Cloud Properties from AIRS: Cirrus, and initial comparisons to CloudSat

by

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AIRS Science Team Meeting

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Outline

- **Fast model retrievals of thin cirrus cloud optical depth (τ_{VIS}) and effective diameter (D_e)**
  - An illustrative AIRS granule
  - Global oceanic ± 30° latitude statistics for September 6th, 2002
    - Version 4 versus 5
  - Comparison to MODIS Collection 4 operational τ_{VIS} and D_e

- **Initial comparisons of AIRS operational cloud fields to CloudSat**
  - A few vertical x-sections of AIRS cloud top height (Z_C) and effective cloud fraction (f) for both layers

- **Ongoing and future work**

The fast retrieval approach

- **Combine OPTRAN clear-sky radiances with a thin cirrus parameterization**
  - Clear + cloudy sky used to fit AIRS radiances [*Yue et al., J. Atmos. Sci.* 2006]

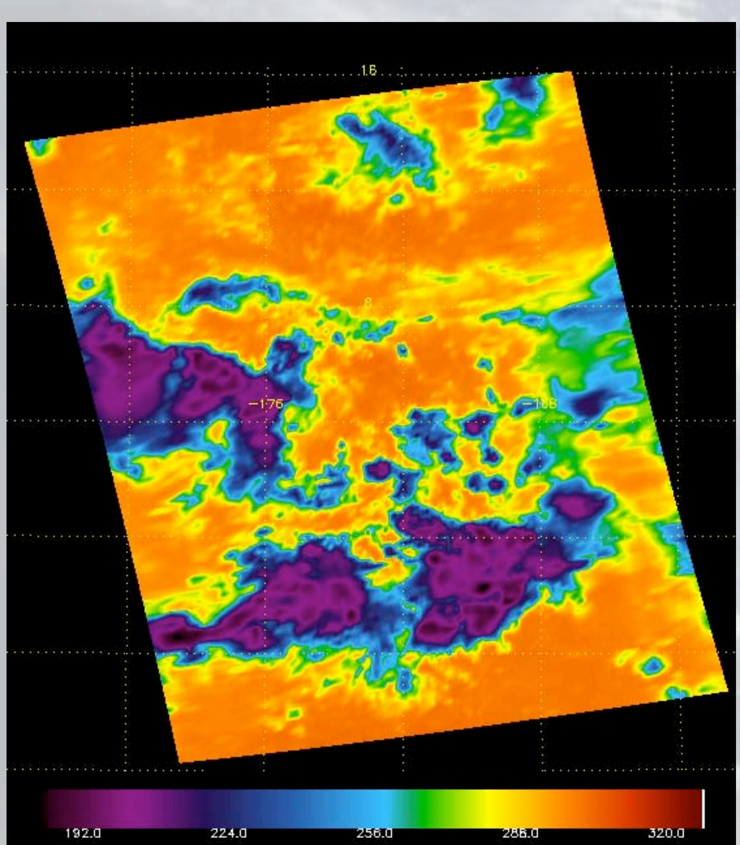
- **Cirrus represented by series of D_e distributions using assumed habit models**
  - Here we use *Baum et al.* [2005] models

- **Minimize χ^2 of observed and simulated AIRS radiances: best τ_{VIS} and D_e**

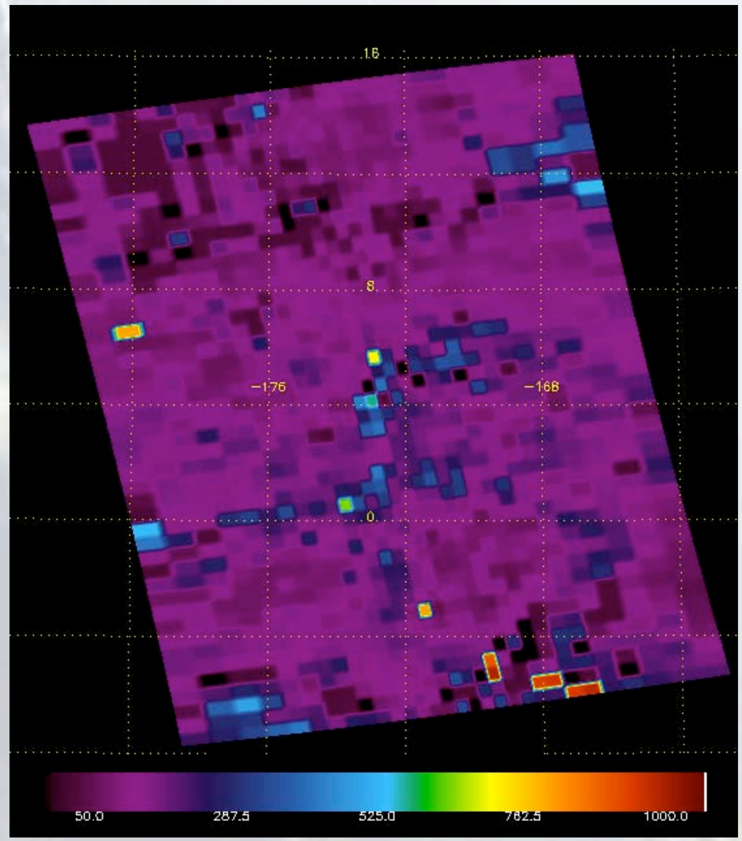
- **Valid for ice clouds with:**
  - $\tau_{VIS} \leq 1.0$ (retrieved using thermal IR, but converted to visible optical depth)
  - $10\ \mu m \leq D_e \leq 120\ \mu m$
  - Single-layered cloud (according to AIRS)

- **Explore relationships between T_C, D_e, τ_{VIS}, etc.**
  - An example granule
  - Global oceans ±30° latitude

An Illustrative Granule: September 6th, 2002, granule 10

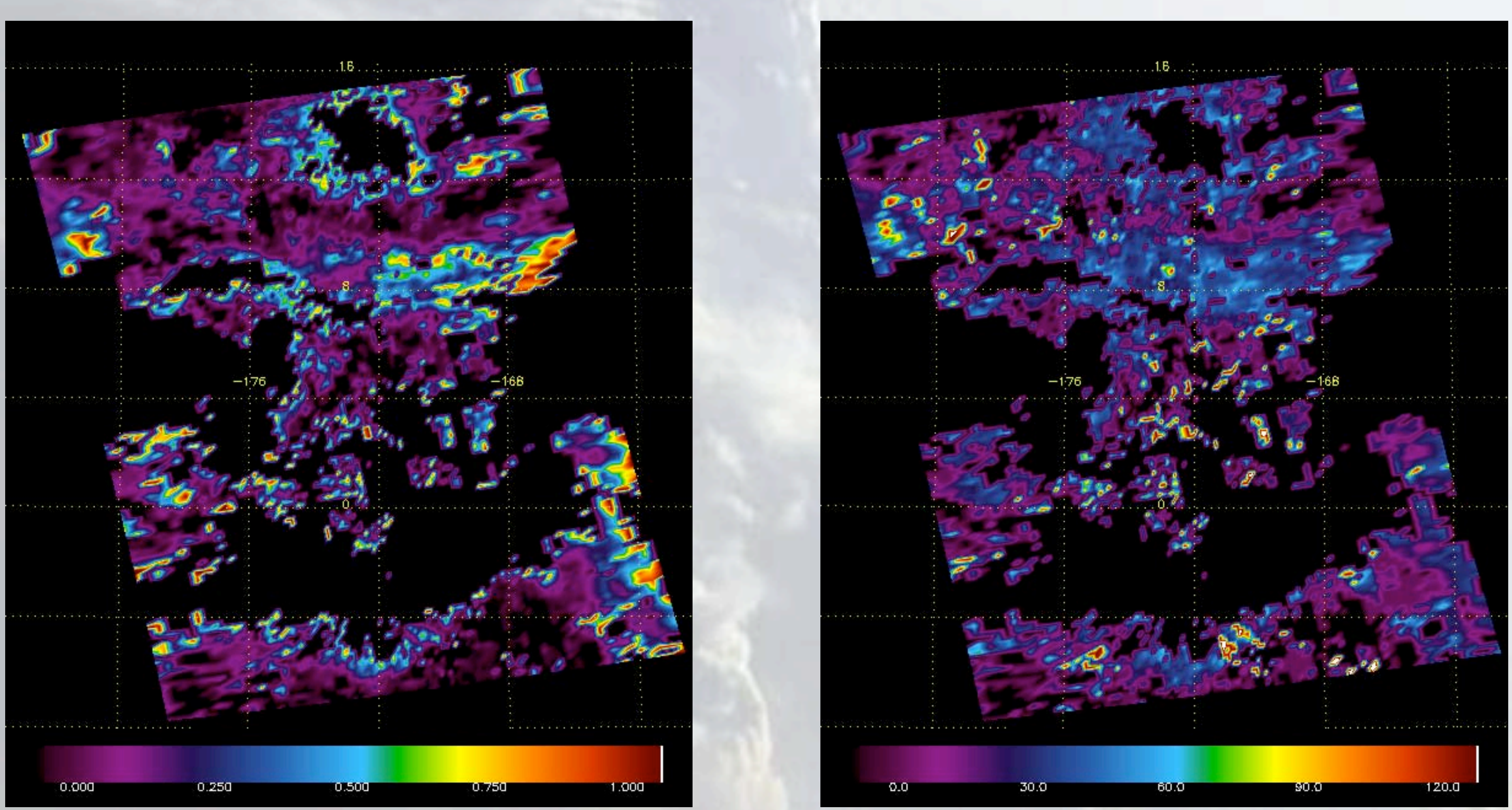


T_b @ 960 cm^{-1} (K)



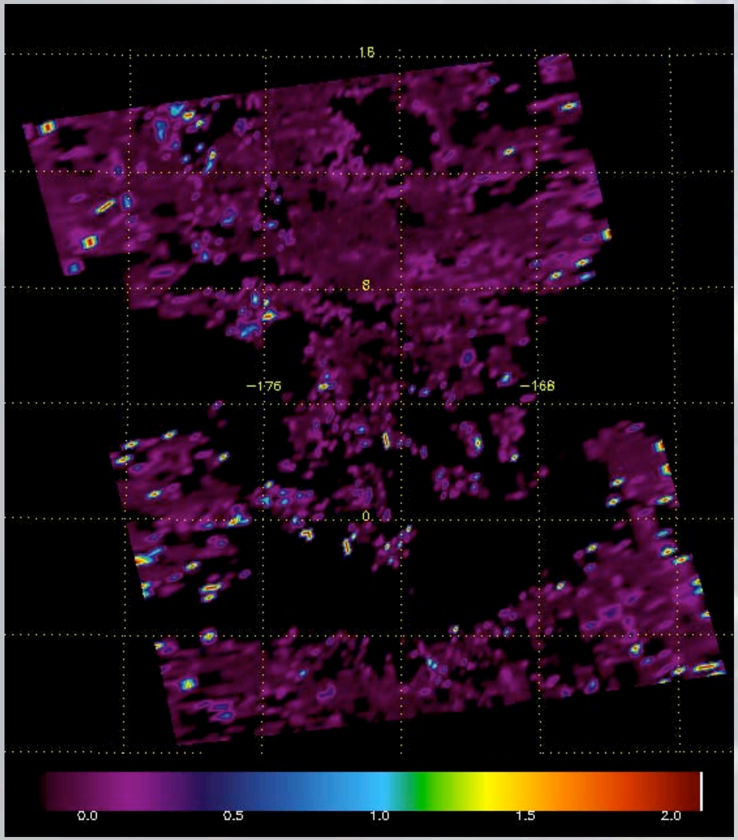
Upper CTP (hPa)

Optical depth (left) and effective diameter (right) retrievals

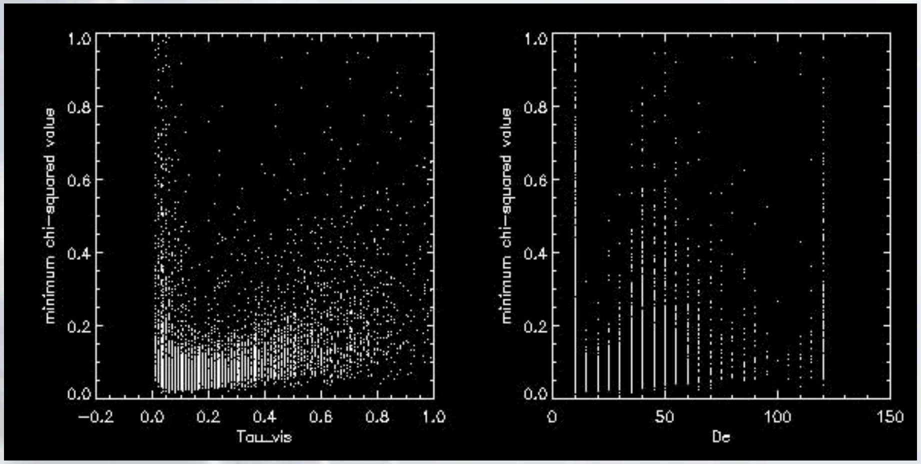


τ_{VIS} D_e (μm)

Minimum χ^2 versus optical depth and effective diameter



Minimum χ^2



Minimum χ^2 vs. τ_{VIS}

Minimum χ^2 vs. D_e (μm)

In situ r_e-T_C Relationships

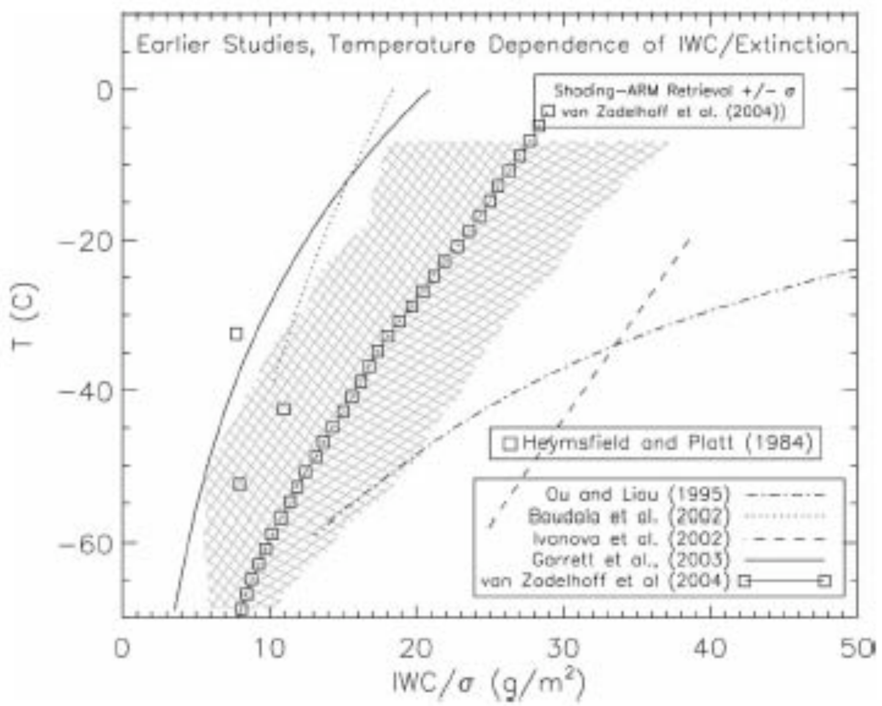
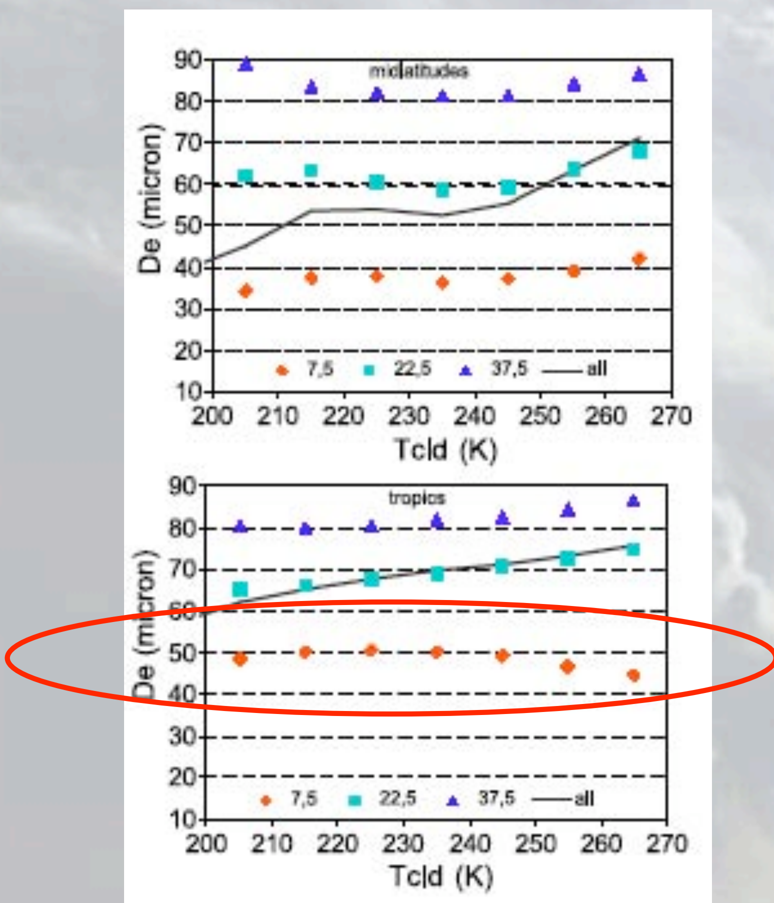


FIG. 1. Estimates of the ratio of ice water content to extinction from earlier studies.

- IWC/σ used as a proxy for r_e
- Increasing r_e with T_C
- Significant differences from different in situ campaigns and modeling studies
- Use to compare against AIRS

Heymsfield et al., J. Atmos. Ocean Tech. [2006]

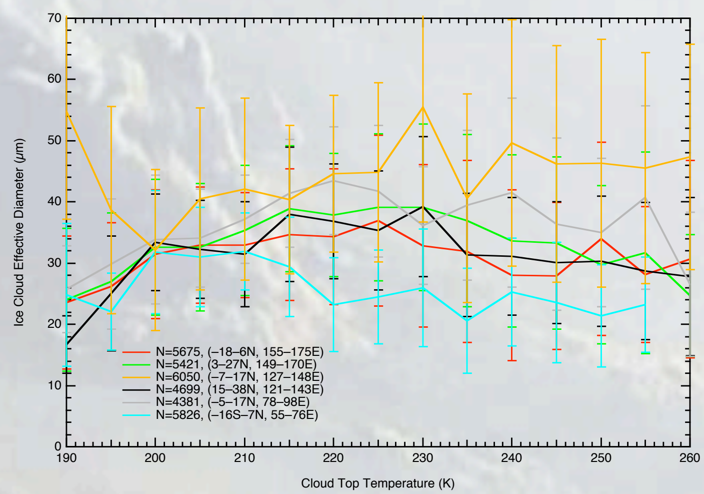
TOVS Path B D_e-T_C Relationships



- TOVS Path-B + ECMWF re-analysis (left)

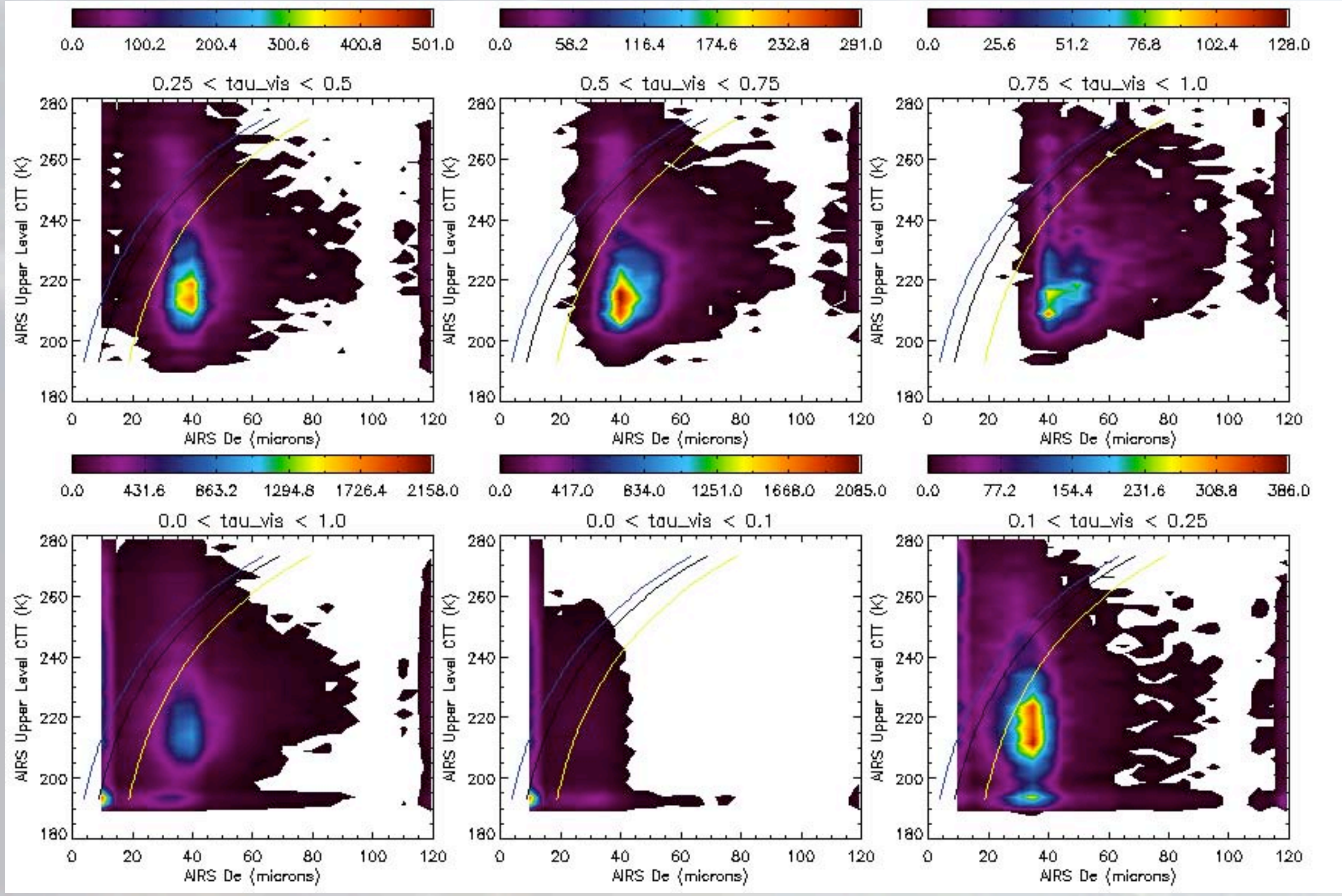
- Generally increasing D_e with T_C
  - However, not necessarily true of thinnest cloud in tropics!
  - Same pattern seen with AIRS retrievals (below)

- TOVS D_e > AIRS D_e



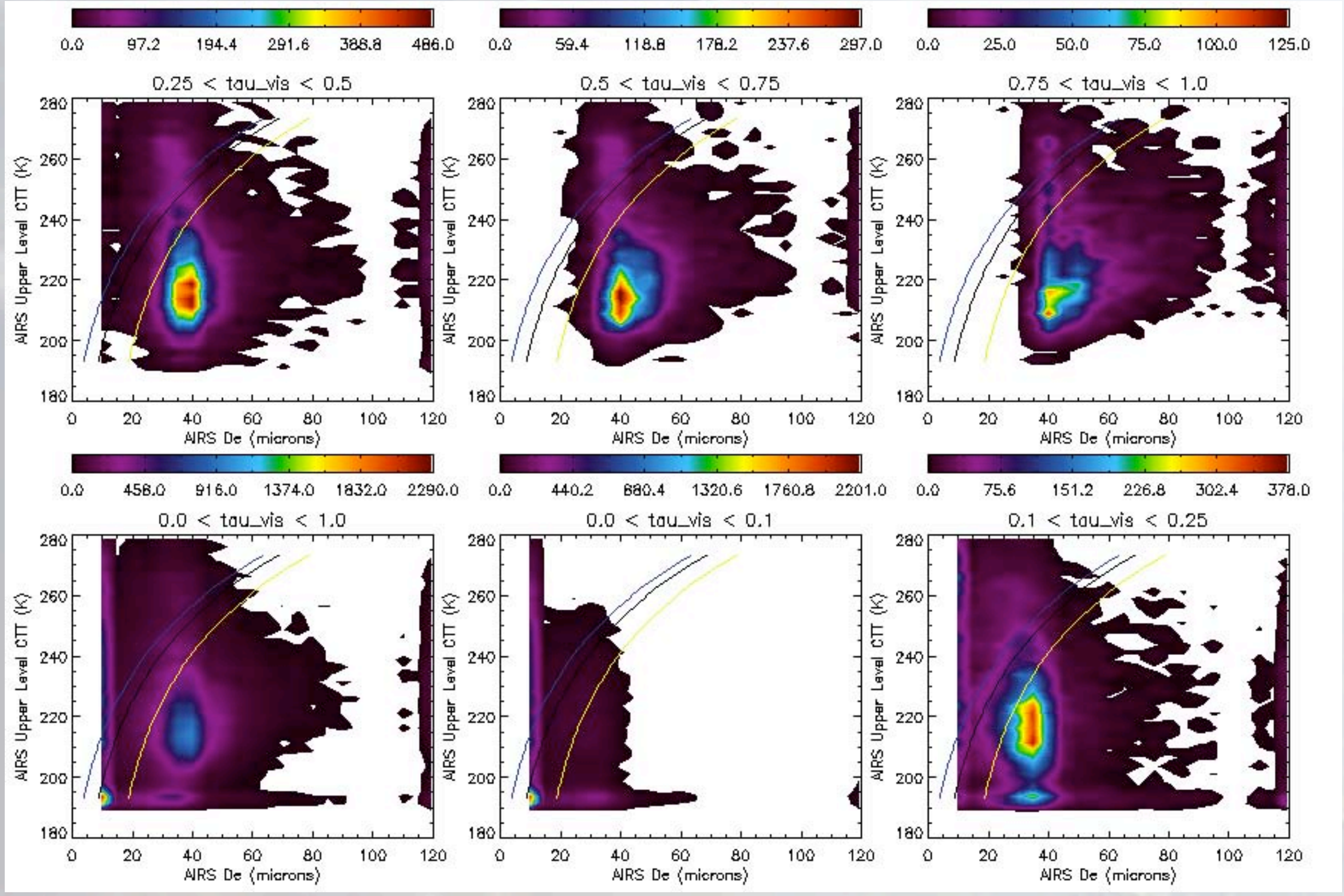
Stubenrauch et al., Atmos. Res. [2004]

AIRS D_e vs. T_C for Varying Optical Depth (V4)



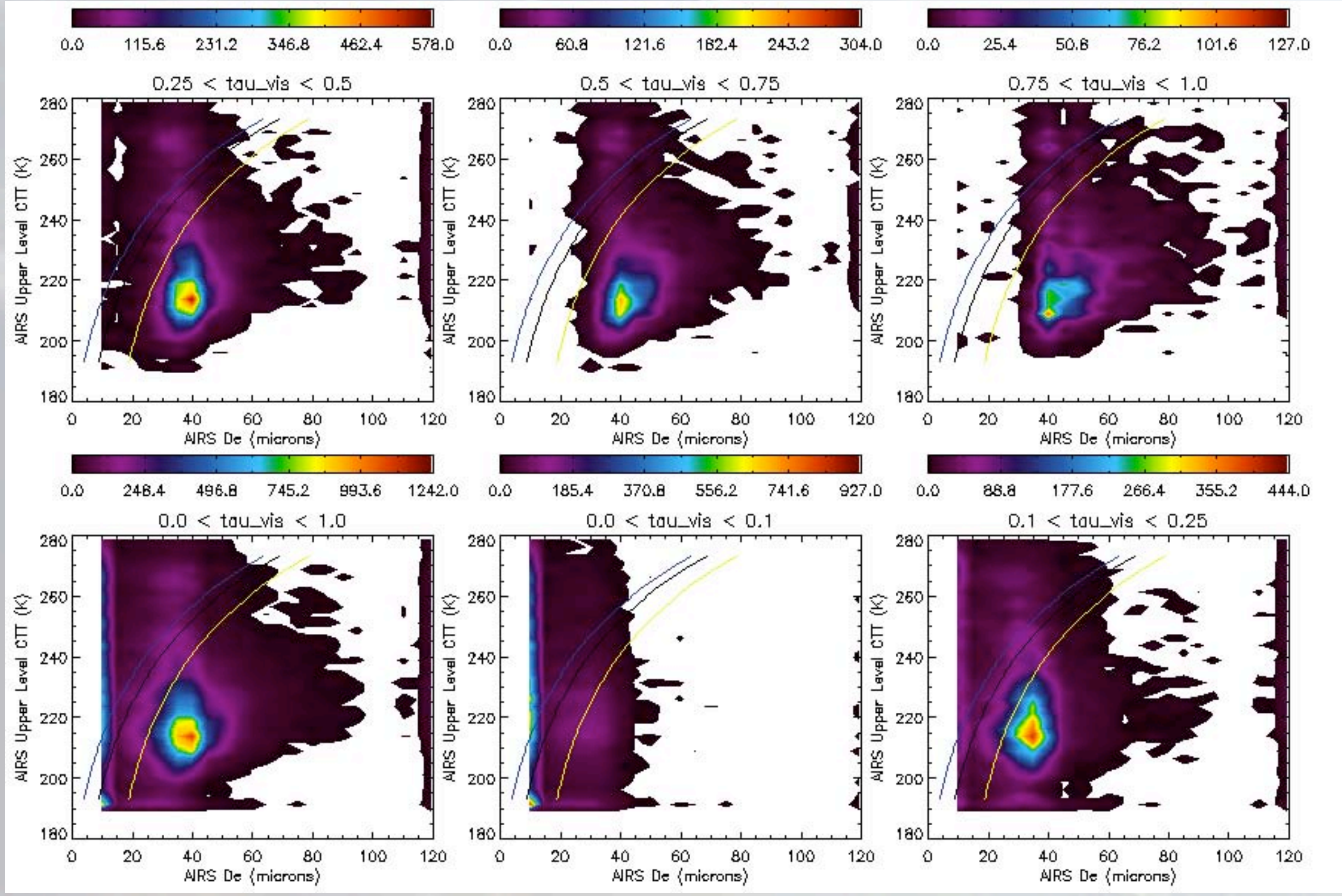
Middle curve: *Garrett et al.* [2003] T_C vs. r_e; 1-σ curves on either side

AIRS D_e vs. T_C for Varying Optical Depth (V4, alt channel list)



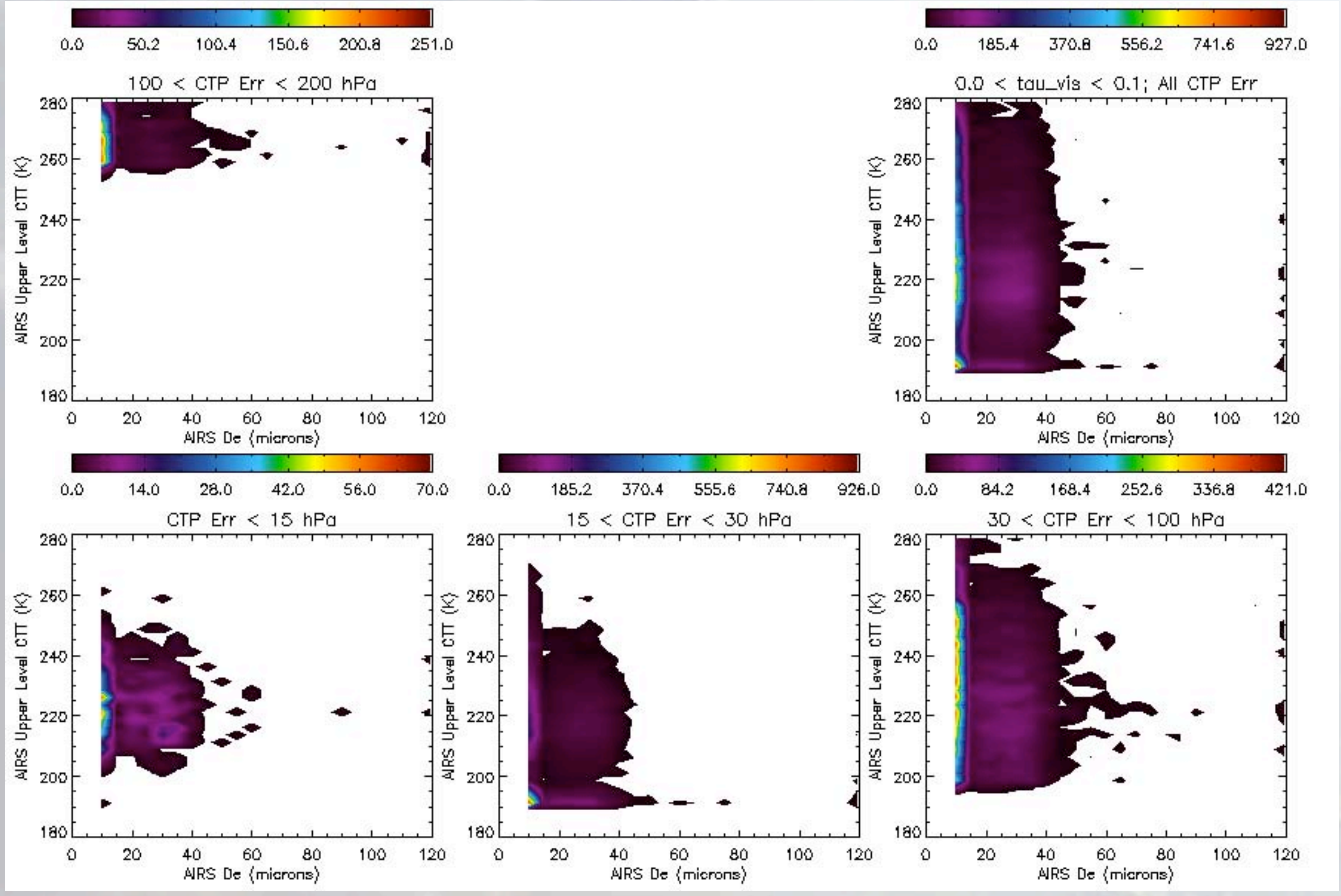
Middle curve: *Garrett et al.* [2003] T_C vs. r_e; 1-σ curves on either side

AIRS D_e vs. T_C for Varying Optical Depth (V5)



Middle curve: *Garrett et al.* [2003] T_C vs. r_e; 1-σ curves on either side

AIRS D_e vs. T_C for Varying T_C Error (Version 5)



Summary of Thin Cirrus Tendencies

- Two D_e modes (10–15; 25–50 μm) at lowest τ_{VIS}
- Smallest mode fades away at larger τ_{VIS}; larger mode increases in D_e with τ_{VIS}
- Small D_e mode composed of mixture of small and large T_C error: probably a real feature, but less robust than larger D_e mode
  - Version 4 and 5 comparisons + channel sensitivity highlight tenuous nature of small D_e mode
- Variable correlation of τ_{VIS} and T_C across various ranges of D_e

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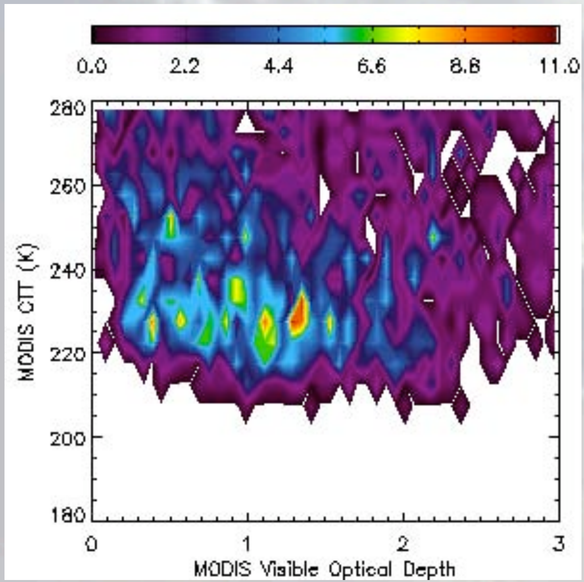
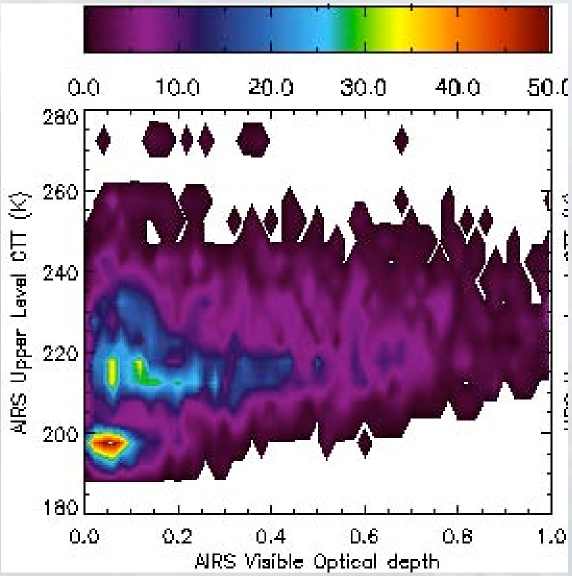
Pasadena, California

Atmospheric Infrared Sounder

MODIS and AIRS Optical Depth

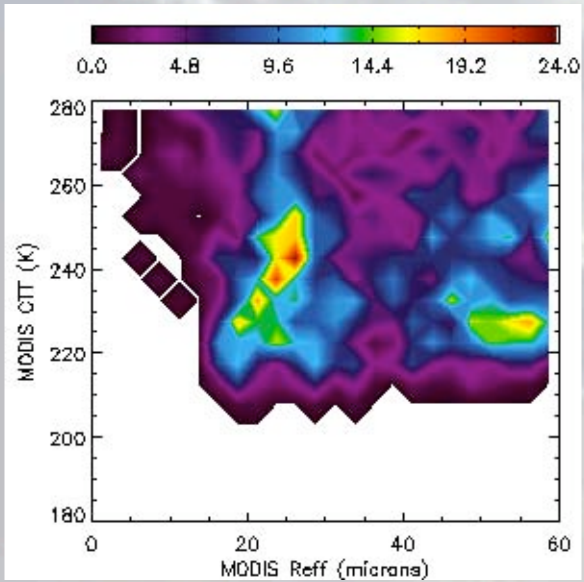
- Collocated, single-layer (according to AIRS), ECF ≤ 0.4 only
- For Granule 11 on September 6th, 2002 only
- AIRS clouds optically thinner and colder than MODIS
- Most MODIS retrievals warmer than 280 K: water clouds

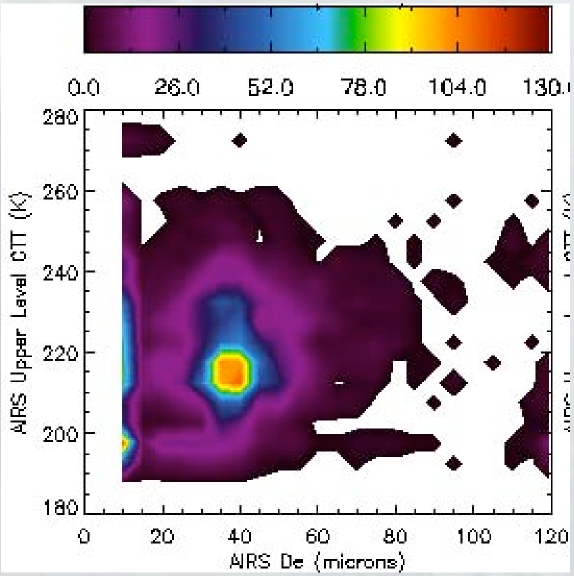




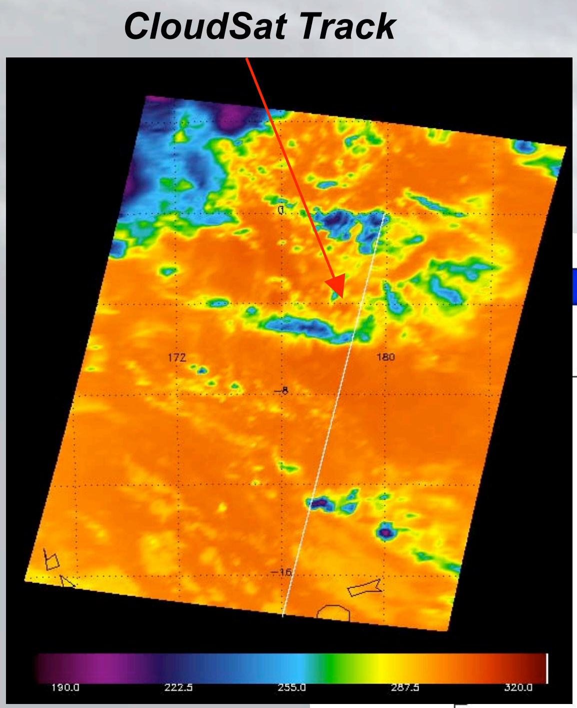
MODIS and AIRS Particle Size

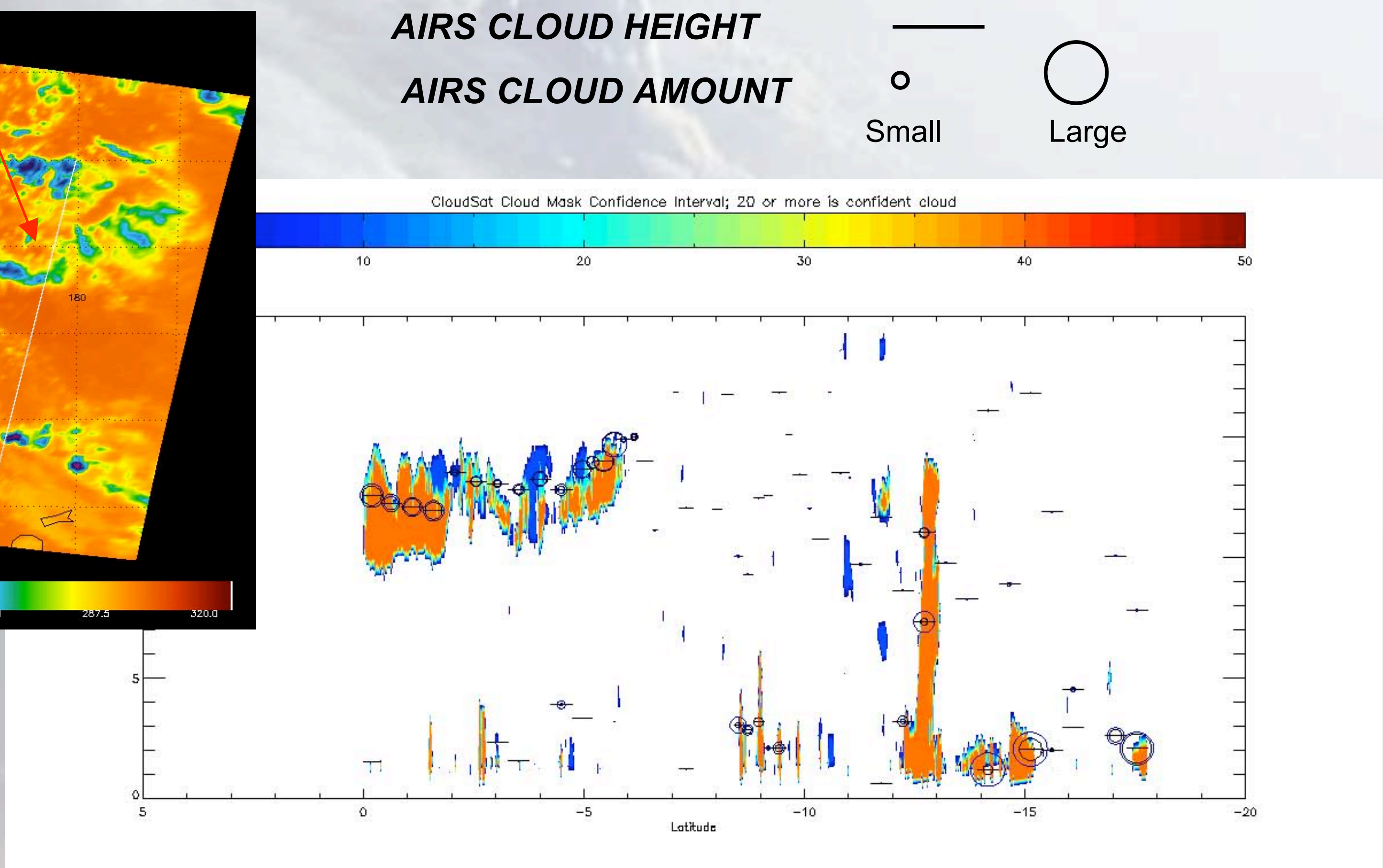
- AIRS and MODIS see two particle modes, but AIRS with D_e = 10–15 μm
- MODIS $r_e = f(T_C)$ near 20 μm
- Also hint of third large mode in AIRS for similar particle size as MODIS





CloudSat Cloud Mask + AIRS 2-layer Clouds

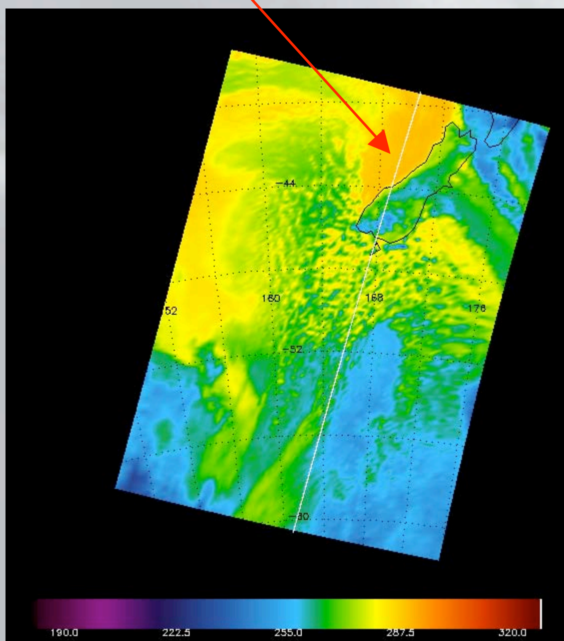




Isolated tropical convection

CloudSat Cloud Mask + AIRS 2-layer Clouds

CloudSat Track

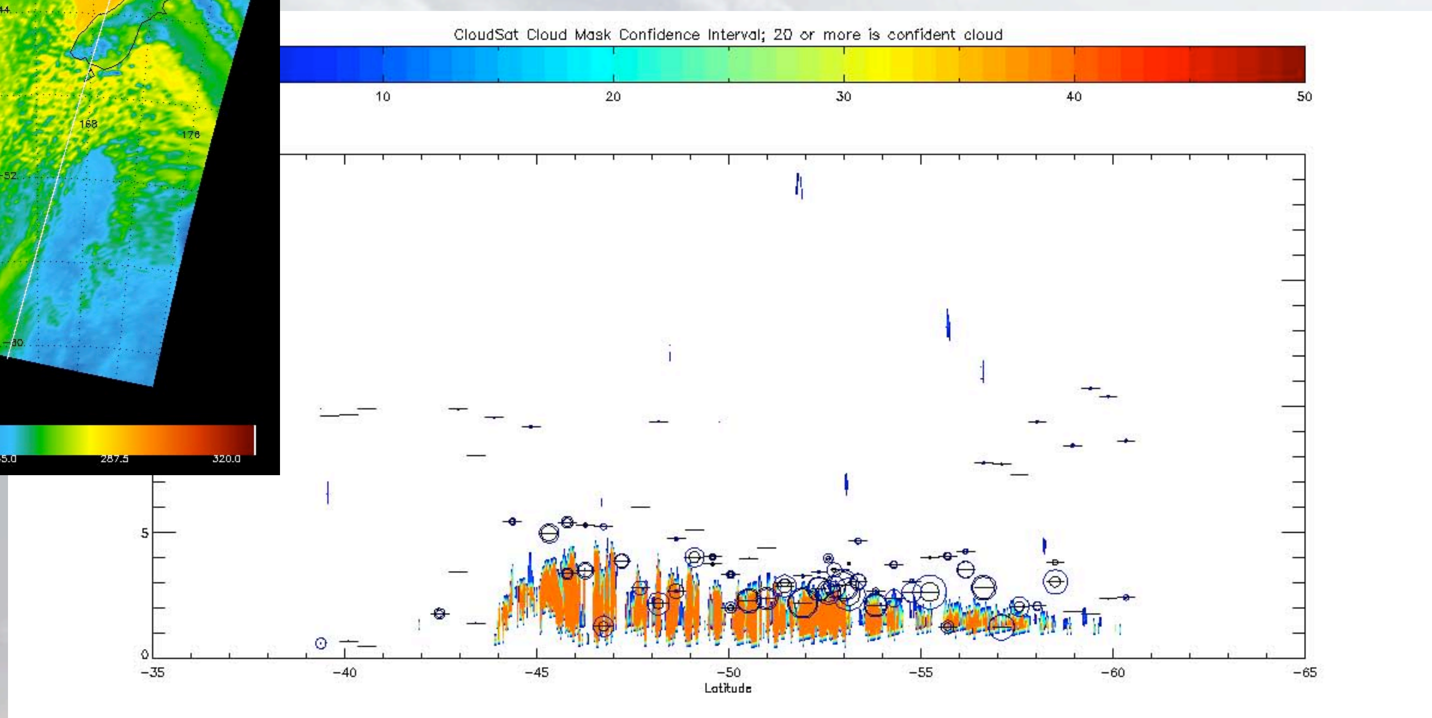


AIRS CLOUD HEIGHT

AIRS CLOUD AMOUNT

Small

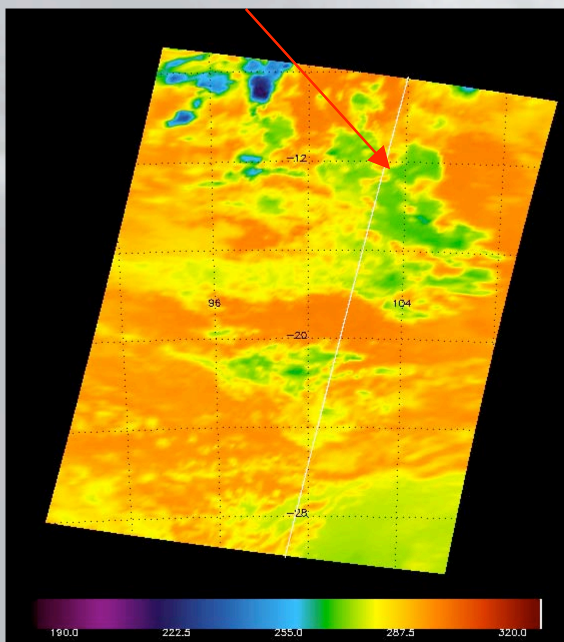
Large



Southern ocean cold air Cu and St

CloudSat Cloud Mask + AIRS 2-layer Clouds

CloudSat Track

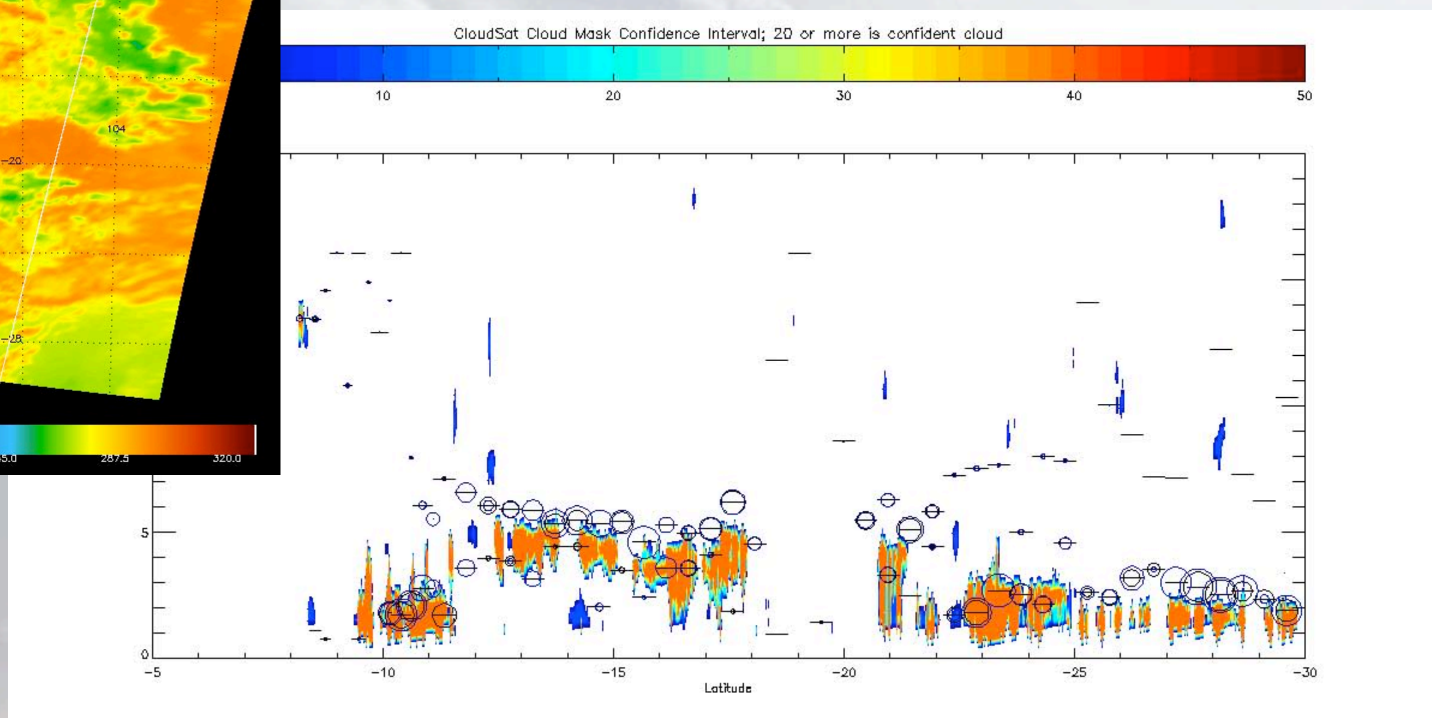


AIRS CLOUD HEIGHT

AIRS CLOUD AMOUNT

Small

Large



Subtropical low and midlevel cloudiness

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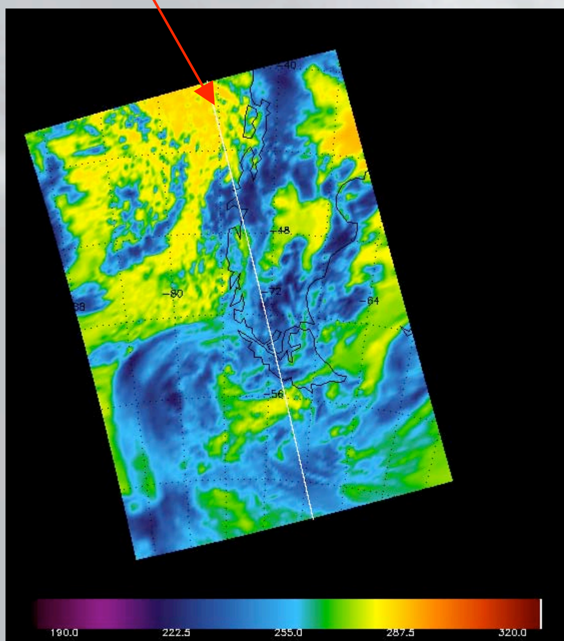
CloudSat Cloud Mask + AIRS 2-layer Clouds

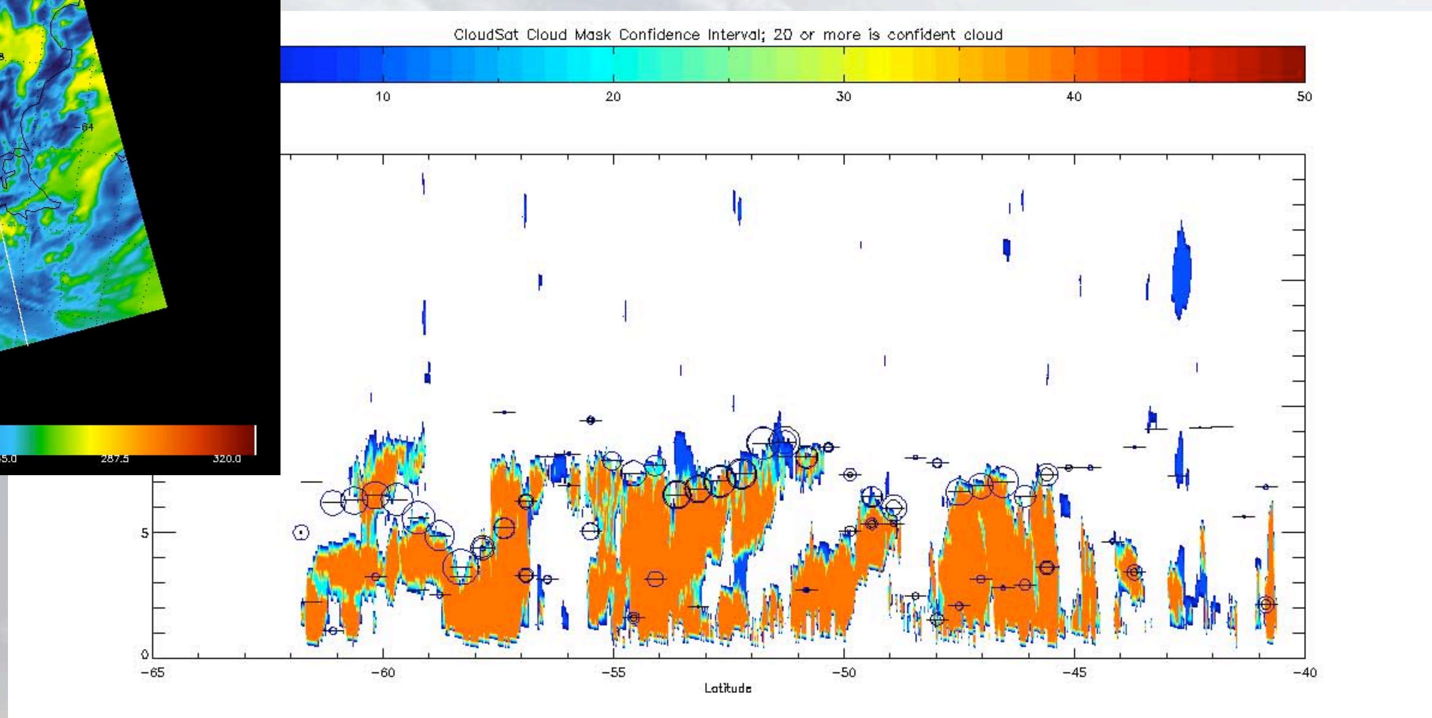
CloudSat Track



AIRS CLOUD HEIGHT

AIRS CLOUD AMOUNT

Small   Large



Winter storm in southern hemisphere

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Atmospheric Infrared Sounder

CloudSat Cloud Mask + AIRS 2-layer Clouds

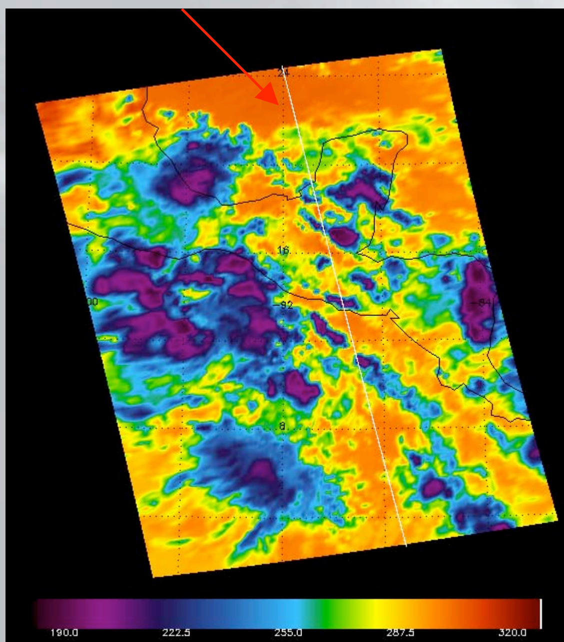
CloudSat Track

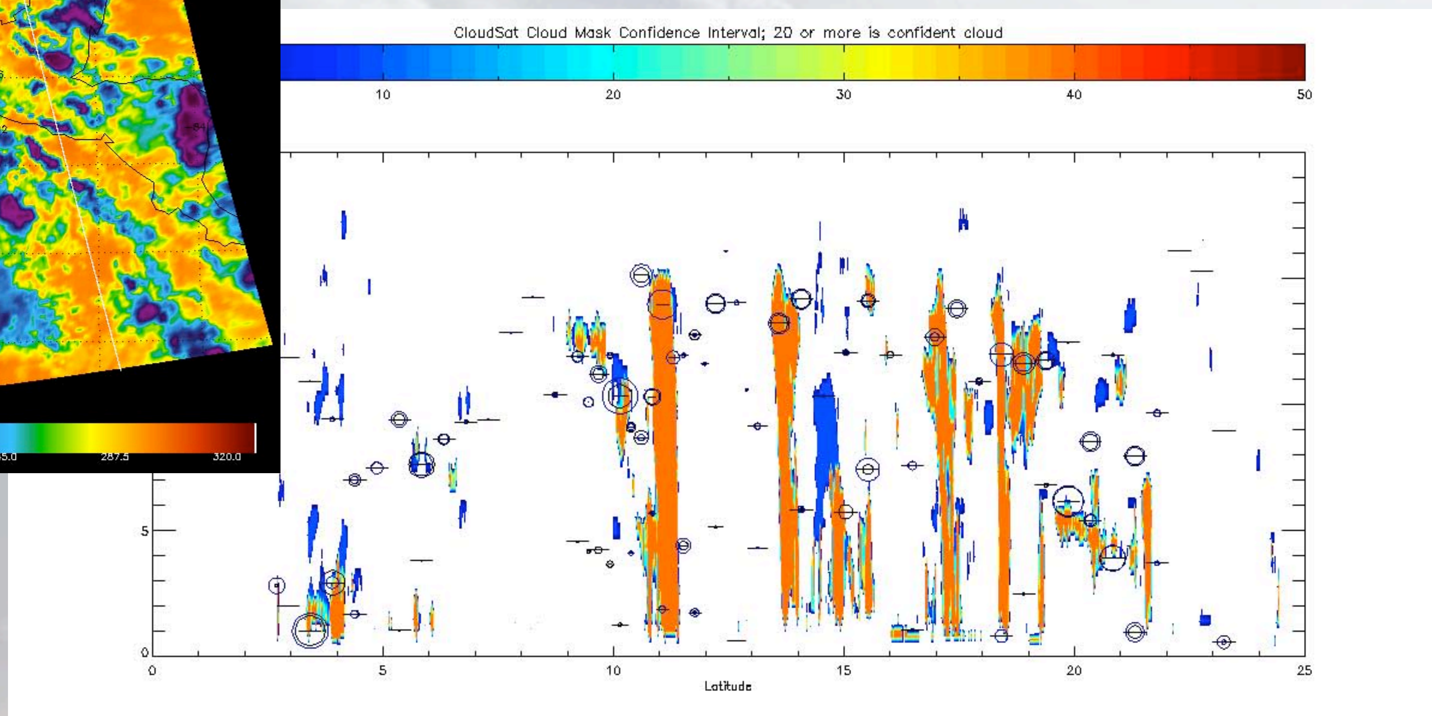
AIRS CLOUD HEIGHT

AIRS CLOUD AMOUNT

Small

Large





Scattered Cbs and Ci

Summary and Conclusions

- **Thin cirrus retrievals reveal bi-modal particle size behavior; not inconsistent with tropical cirrus clouds**
  - Uniform, tenuous, laminar, small particle size > 15 km
  - Thicker, structured, larger particle size < 15 km (e.g., *Comstock et al., J. Geophys. Res*. [2002])
  - Need to explore why bi-modal in AIRS, not as much as *in situ* data

- **Matched-up MODIS cirrus retrievals show systematic differences to AIRS**
  - Larger optical depth and particle size at lower altitudes
  - AIRS picks up mode near 10-15 μm, MODIS does not

- **CloudSat comparisons reveal usefulness of 2-layer AIRS clouds**
  - CALIPSO will better determine validity of small particle mode in AIRS

Current and Future Work

- **Retrieve thin cirrus properties for longer time periods**
    - Differences for land/ocean, day/night, V4 and V5, channel selection, etc.
    - Seasonal, regional, latitudinal dependencies?
    - Further comparisons to MODIS: IR versus VIS/near-IR retrieval methods

- **Collaboration with UCLA, modification to include scattering**
    - How do results change with different sampling of cirrus clouds (e.g., thin vs. thin+thick)?
    - Further comparisons to *in situ*, satellite data (e.g., MODIS)
    - Cirrus retrievals in V6 as suggested by L. Strow?

- **Further comparisons with CloudSat as more data is released**
    - Global statistics, IWC/LWC profiles, cloud typing
    - Fold in CALIPSO data
    - Fold in MODIS to understand heterogeneity, cloud type sensitivity, etc.